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Spatial Information Network Modeling and Analysis Based on Cognitive Technology

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Abstract

Aiming at ubiquitous and heterogeneous network model, spatial information network was constructed for the complex space environment, real-time adjustment to configure the network system, dynamicly and intelligently adapting to the environment and guiding future independent decision. There are corresponding theoretical guidance and support mechanisms on the network dynamic sensing and self-healing capabilities. Starting from the mechanism of cognitive technology, the concept of cognitive spatial information network was defined, the role of feedback loops in the cognitive process was elaborated, and the characteristics of the cognitive spatial information network was analyzed. A hierarchical cognitive network design model was proposed. For the initiative aware features of the network, the model uses the energy spectrum sensing method in cognitive radio and qualitatively analyzes the perceived performance of the cognitive spatial information networks. The simulation results show the range of the algorithm applied in space information network.

Keywords

Cognitive Technology; Spatial Information Network; Spectrum Sensing

Introduction

Future space information network is a ubiquitous, heterogeneous network model, with multiple access methods coexisted, multi-node work together, supporting seamless mobility characteristics in varying degrees.Spatial information network based on cognitive technology (referred to as cognitive Spatial Information Network) is an important program to achieve future communication networks. Cognitive spatial information network can gather information around the network environment and learn, and then dynamically adjust and reconstruct the network. Currently, cognitive spatial information network with its combining resource management to maximize overall network performance and other advantages became the research hotspot.

Cognitive Spatial Information Network Design and Implementation

Cognitive Spatial Information Network Features

Cognitive process is the core of the cognitive spatial information network, its greatest feature is the ability of cognition and learning. Therefore, cognitive spatial information network requires a cyclic feedback on past decisions and the current environment, decision-making and future interaction between the current environment and achieve the cognitive process, which includes four modules, Observe, Orient, Decide and Act.

Cognitive Spatial Information Network Model Design

Figure 1 shows the spatial information network hierarchical model, it introduces the OODA loop into each layer of the modeland analyzes its role in each layer and the key technologies required. The purpose of introducing the cognitive processes in the physical layer is to percept the information on the surrounding physical airspace, the node parameters including transmit environment. The main purpose of the cognitive process in the data link layer is to obtain the use of the network spectrum and then select a suitable scheduling policy. The main purpose of the cognitive processes in the network layer is to learn the network topology around, and choose the best routing strategy. The main purpose of the cognitive processes in the application layer is to better understand the needs of

users and services, so as to better provide services.

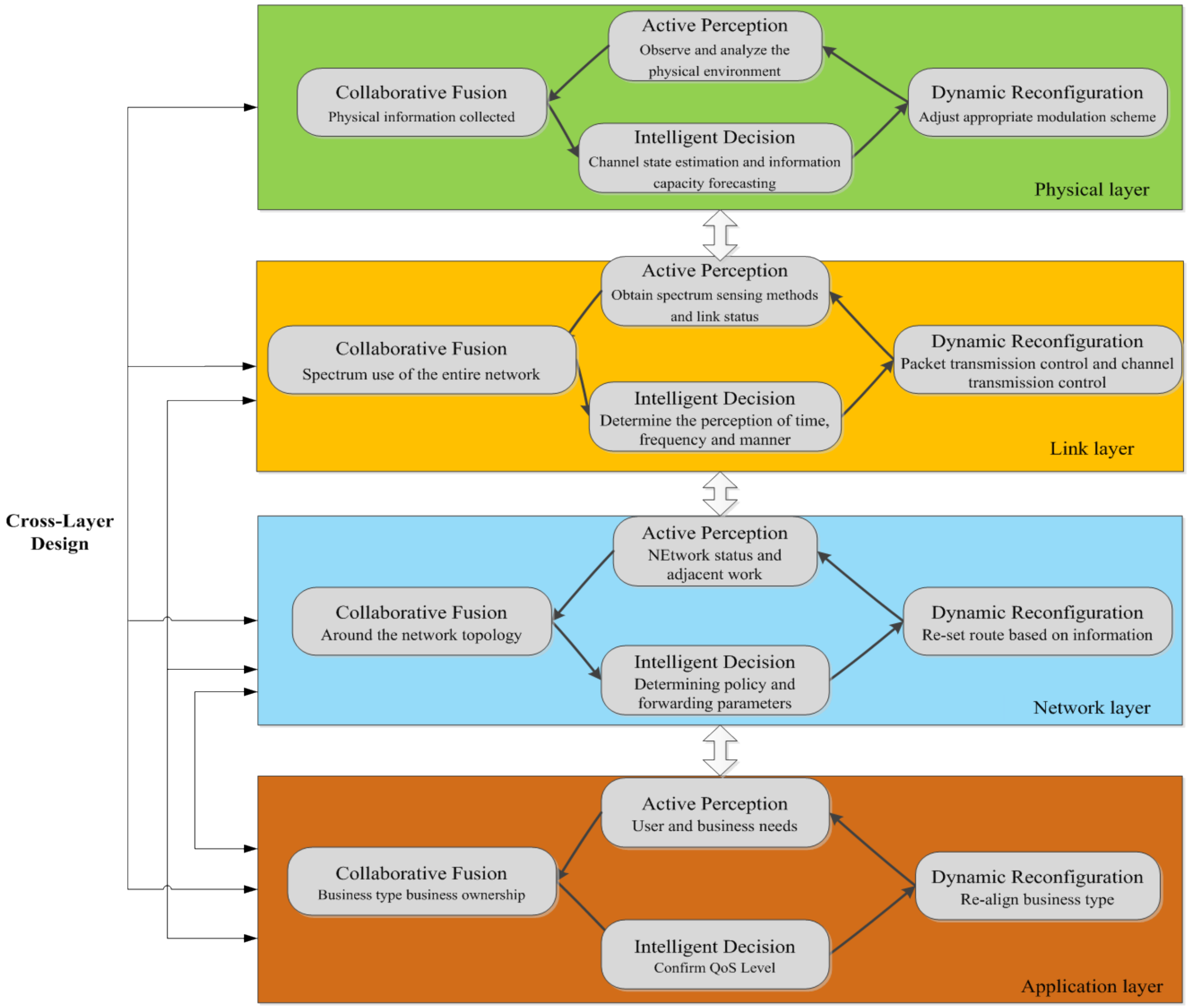


FIG.1 COGNITIVE SPATIAL INFORMATION NETWORK MODEL

Spectrum Sensing Algorithm Based on Energy Detection

The main idea of energy detection: average PU signal power $x(k)=x_I(k)+jx_Q(k)$ at a time period (K sampling points), and then compare with the preset threshold, determine whether the frequency band has PU signalt.

$$p(k)=\frac{1}{K}\sum_{i=0}^{K-1}\left|x(k+i)\right|^2 \tag{1}$$

In satellite communication the received signal is a direct signal, multipath and fading factors do not exist, which can be seen as a $AWGN$ channel. In $AWGN$ channel,the binary detection model can be written as

$$\begin{aligned} H_0 &: x(t)=n(t) \\ H_1 &: x(t)=s(t)+n(t) \end{aligned} \tag{2}$$

Where, the bilateral power spectral density of $n(t)$ is N_{02}, the bandwidth is W; $s(t)$ is the unknown deterministic signal. According to Shannon sampling theorem we can obtain:

$$n(t)=\sum_{-\infty}^{\infty}a_i \sin c(2wt-i) \tag{3}$$

Where, $a_i = n\left(\frac{i}{2w}\right)$, $\sin cx = \frac{\sin \pi x}{\pi x}$

In $(0,T)$, $n(t)$ is approximated by 2TW samples,

$$n(t) = \sum_{i=1}^{2TW} a_i \sin c(2wt - i),\ 0 < t < T \tag{4}$$

Similarly, the signal $S(t)$,

$$S(t) = \sum_{i=1}^{2TW} \alpha_i \sin c(2wt - i) \tag{5}$$

Where, $\alpha_i = n\left(\frac{i}{2w}\right)$. 令 $b_i = \frac{a_i}{\sqrt{2WN_{02}}}$

In the assumption of H_0, Test statistic V can be expressed as

$$V = \sum_{i=1}^{2TW} b_i^2 \sim \chi_{2TW}^2 \tag{6}$$

Set $\beta_i = \frac{\alpha_i}{\sqrt{2WN_{02}}}$, In the assumption of H_1, Test statistic V can be expressed as

$$V = \sum_{i=1}^{2TW} b_i^2 + \beta_i^2 \sim \chi_{2TW}^2 \left(\lambda = \sum_{i=1}^{2TW} \beta_i^2 \equiv \frac{E_s}{N_{02}}\right) \tag{7}$$

For a given threshold $V_T^{'}$, the probability of false alarm P_f is:

$$P_f = P\left\{V > V_T^{'} \middle| H_0\right\} = P\left\{\chi_{2TW}^2 > V_T^{'}\right\} \tag{8}$$

Similarly detection probability has:

$$P_d = P\left\{V > V_T^{'} \middle| H_1\right\} = P\left\{\chi_{2TW}^2 > V_T^{'}\right\} \tag{9}$$

In AWGN channel, the expressions of the detection probability P_d and false alarm probability P_f as follows:

$$P_d = Q_{TW}\left(\sqrt{\lambda}, \sqrt{V_T^{'}}\right) \tag{10}$$

$$P_f = \frac{\Gamma\left(TW, \frac{V_T^{'}}{2}\right)}{\Gamma(TW)} \tag{11}$$

$Q_u(a,b)$ is the generalized Marcum Q function, $\Gamma(a,b)$ is a non-fully gamma function. When 2TW> 250, use a Gaussian distribution to approximate the detection statistic under two assumptions (H_0, H_1), and we can get better results.

Therefore, under the assumption of H_0:

$$P_f = \frac{1}{2} erfc\left[\frac{V_T^{'} - 2TW}{2\sqrt{2TW}}\right] \tag{12}$$

Where, $erfc[z] = \frac{2}{\sqrt{\pi}} \int_z^{\infty} \exp\left(-x^2\right) dx$

However, under the assumption of H_1:

$$P_d = \frac{1}{2} erfc\left[\frac{V_T' - 2TW - \lambda}{2\sqrt{2(TW+\lambda)}}\right] \tag{13}$$

Spectrum Sensing Process and Simulation Analysis

Spectrum Sensing Process

By calculating the cross-correlation value between the received signal mean power value and the pre-stored power spectrum value, sensing the method most likely being used of integrated channel can be perceived. At the same time, the channel sensing can derive a set of channel usage, through estimating one channel occupancy in order to simplify the calculation of channel sensing. After the analysis above, the algorithm process implemented spectrum sensing in the network physical layer shown in Figure 5

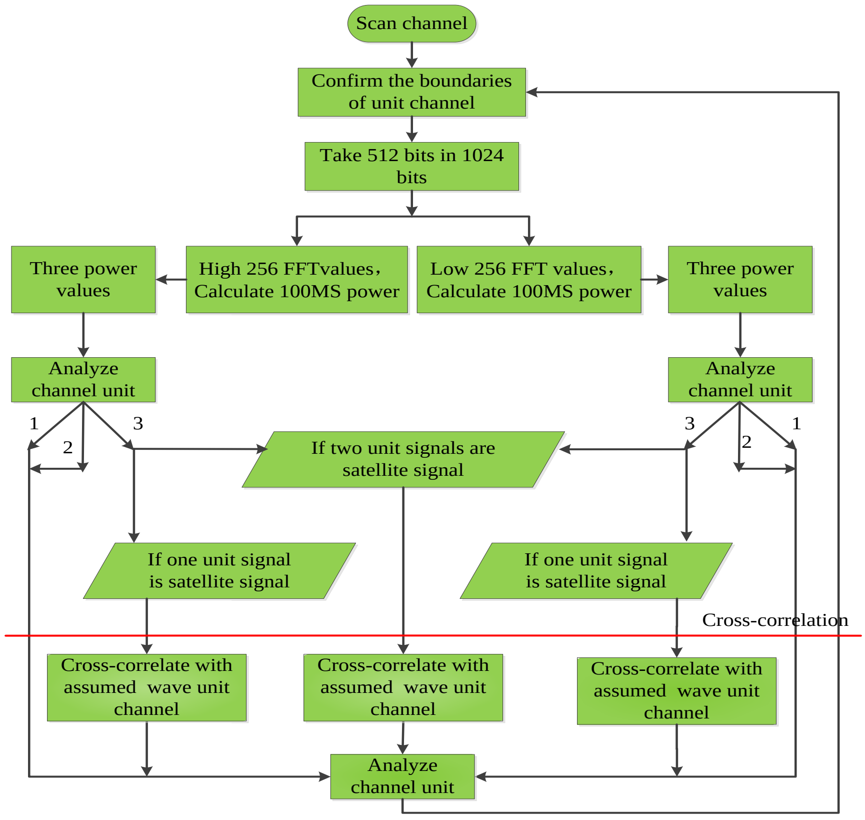
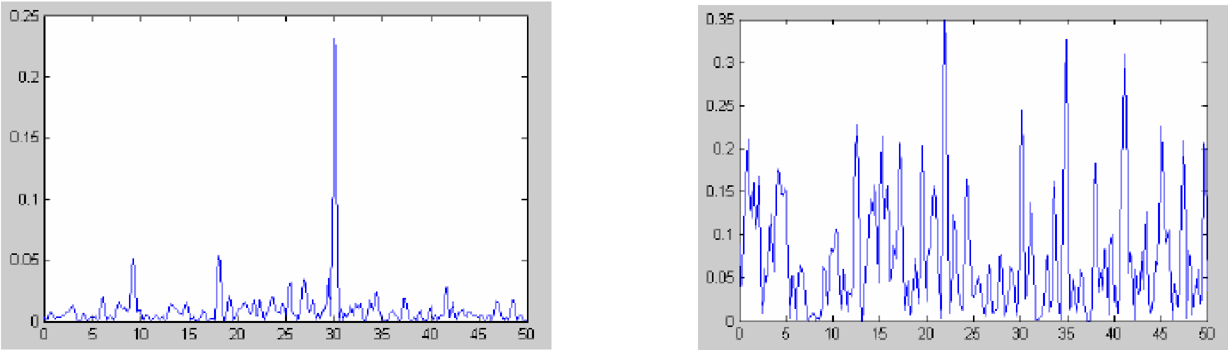


FIG. 2 CHANNEL SENSING ALGORITHM PROCESS

Simulation and Verification

Assuming sampling frequency fs = 100Hz , the carrier frequency fc = 30Hz, rate f0 = fs / 20. Signal to noise ratio SNR is taken as -5dB, assuming a center frequency of the energy detector is aligned precisely with the center frequency of the received signal, the bandwidth of energy accumulated is twice of the symbol rate (ensuring energy detector maximum has the maximum energy accumulation), the spectrum detection figure using the energy detection method shown in Figure 3.

The signal used the energy detection method to achieve energy detection. Parameter settings are as follows: 10.7MHz IF, 60MHz sampling rate, 1024 points FFT, 10 times 10 frequency point average. Respectively simulate at SNR = -5dB and SNR = -15dB case, the results shown in Figure 3. Seen from Figure 3, when the SNR is relatively high SNR = -5dB, the peak of FFT results of the signal apparent, threshold setting is relatively simple, and therefore, the signal can be detected by the energy detection method. However, when the SNR is relatively low SNR = -15dB, the noise signal is submerged, there is no obvious peak after FFT, then the signals can not be detected. The energy detection method can be applied in the case with relatively high signal to noise ratio.



(a)SNR=-5dB (b) SNR=-15dB

FIG.3 ENERGY DETECTION SPECTRUM

Conclusion

Cognitive spatial information network is a kind of intelligent networks, which can observe the surrounding environment, according to the end-goal use the appropriate learning mechanism, make proper planning, decision and action for the network status. Future communication network requires more intelligence, and needs a network with self-configuration, self-optimization and other features. These goals bitterly fit the cognitive network characteristics, therefore, the spatial information network develops towards the cognitive technology is an important trend in the future.

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